Atmospheric water vapour processing

by Roland Wahlgren

Even the driest air around us contains water vapour, which can be extracted and used. Designs already exist for devices that process atmospheric water vapour into liquid potable water, and this area deserves to be explored.

FACED WITH THE challenge of providing a community with a safe water supply, the fieldworker may wonder if there are ways to tap into a clean water source other than by pumping. Gathering water vapour directly from the atmosphere and changing it into liquid water could be an innovative option. Over a dozen patents for water vapour processors have been issued during the past two decades, but the technology remains untried.

Unconventional water sources such as desalination, tanker transport, iceberg transport, water re-use, and weather modification technologies have been discussed and tried with varying degrees of success for many decades. Desalination is the only process that has become widely used, but it has two major disadvantages: it is expensive, and it creates waste brine, which can pollute groundwater and the environment in the vicinity of the plant if released indiscriminately.

Water gathering methods

There are two ways to gather water directly from the atmosphere: one is to intercept directly suspended water droplets, the other is to extract water vapour out of the air. Figure 1 shows the two different ways of designing an atmospheric water harvester or processor. The choice is either to harvest the water droplets, or to process the water vapour. (Harvesting is gathering the water droplets, because no phase change of the water occurs. Processing seems an appropriate word for machines which cause water to change phase from vapour to liquid.) Three extraction processes are possible: cool a surface to below the dewpoint temperature of the ambient air, (people experience this effect on a small scale whenever they enjoy an iced drink and find the outside of their glass becomes wet); use either liquid or solid adsorbent materials; or induce air convection and control it in a tower-like structure.

The collection of water droplets requires no electromechanical energy input, but the effectiveness of the collectors is dependent on meteorological conditions and seasonal changes in fog and low cloud occurence. Polypropylene mesh fog collectors in Chile have been used to supply 7200 litres of water a day.[1]

Water vapour processing

If the water vapour could be collected directly, there would be no need to locate water collectors only where fog or low cloud prevails. The cost of this freedom, though, is that relatively large amounts of energy are required to transform the water from gas to liquid. The latent heat of vaporization for water is 2.45×10^6 joules/kg at 20°C. This amount of heat is liberated when condensation occurs, and to remove this heat from the vapour requires the same amount of energy.

Patented devices are of interest because they have received a form of scientific review. Fourteen patents are classified according to process type in Table 1, along with their inventor's assessment of water production capability. If prototypes or commercial versions of these designs exist they have not been widely publicized.

Process one A Swedish researcher, B. Hellstrom, conducted experiments into this process in the early 1950s.[2] He used a commercial dehumidifier set up in the Hydraulic Laboratory of the Royal Institute of Technology in Stockholm, and with an airflow of $0.4m^3$ per second and a machine efficiency of 20 to 40 per cent, water output was 50 to 70 litres a day.

Heat-pump-based devices capable of supplying millions of litres of water per day were proposed by scientists at the Lamont Geological Observatory (LGO) and at the Solar Energy and Energy Conversion Laboratory (SEECL), at the University of Florida.

The LGO proposal, for the US Virgin Islands, envisaged cold (5°C) ocean water from a depth of 1000m being pumped up (by a 270kW pump) via a 1.5km-long, 2.5m-diameter pipeline into a 200m-long by 10m-high condenser array.[3] A similar proposal by SEECL, which claimed to be suitable for regions from 30°N to 30°S, called for three 200kW wind machines to pump 4.5°C water from a depth of 500m to shore via four 1.22m-diameter plastic pipes into a 129 000m^2 heat-exchanger field. Described by A.K. Rajvanshi in 1981, the project was estimated at the time to have a capital cost of US$11 million. It would have been two-and-a-half times as expensive to build as a comparable capacity reverse-osmosis desalination plant.

Process two T.H. Elmer and J.F. Hyde, who were associated with the Research and Development Laboratories of Corning Glass Works, described the use of various inert carriers, (glass plates, fibrous board, or sand grains) coated with hydrated salts as water vapour adsorbents.[4] They sketched out an idea for a drinking-water collector comprising a flat glass cover over a carrier and dessicant. The device would incorporate a condenser tube, a water collecting trough, and the use of stored water as a coolant. The glass cover would be opened during the night to allow the adsorption of water, and would be closed during the day to

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New and innovative sources of water are always needed.

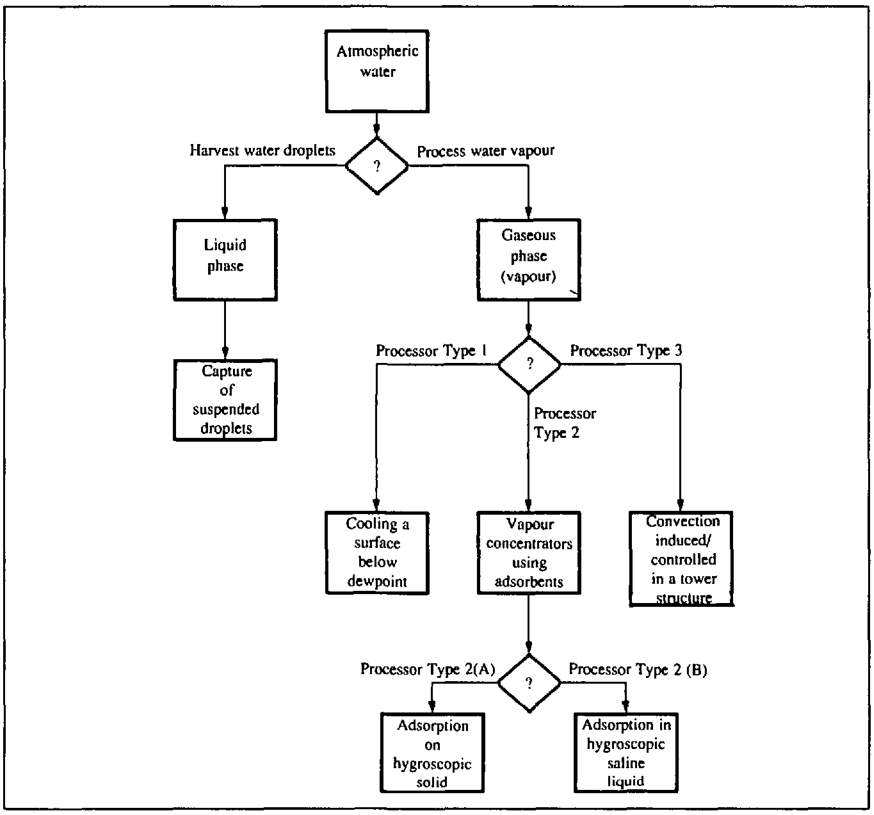

Figure 1. Strategies for gathering atmospheric water.

allow heating by solar energy to release the adsorbed water. This method was estimated in 1986 to cost about six times as much as desalination.

Process three Ambient air is introduced, along with heat, into the base of a vertical tube or tower. The structure is designed to create and sustain a vortex of air much like a tornado. Ockert's 1978 patent, listed in Table 1, gave no dimensions but stated that an 'impressively large structure ... similar to a natural draft cooling tower' would be required. The air cools as it rises within the walls containing it. Condensation and precipitation occurs within the column when the temperature of the rising parcel of air or convection cell drops below the dewpoint. Massachusetts Institute of Technology meteorologists designed an 'aeriological accelerator', a circular cylinder with a radius of 50m extending 3000m up into the troposphere.[5] Hypothetical data generated via a numerical model of the device suggested that an output of two million litres per day could be expected.

Water production requirements

The potential rate of water production from a water vapour processor depends on the absolute humidity of the air at the location, the rate of airflow through the machine; and the efficiency of the device. Absolute humidity on the surface of our planet ranges from 4 to 20 grams of water vapour per cubic metre of air.[6] Paradoxically, some fairly arid regions, such as Bahrain and Djibouti, are surrounded by humid air.

For developing regions it is widely acknowledged that one person's water needs for survival, subsistence, and 'present development goals' are 8, 20, and 40 litres of water respectively.[7]

Hellstrom defined efficiency of water extraction from the atmosphere as:

$$\text{Efficiency} = \frac{\text{Amount of water extracted per unit time}}{\text{Total moisture content of air processed per unit time}^{8}}$$

The daily water volume produced by a water vapour harvesting device is estimated by:

Table 1. Patents issued for devices which condense water vapour out of the air for water supply.

Process type	*Patent*	*Output (litres/day)*	*Remineralization (Yes/No)*
1.	**Cooling a surface to below the dewpoint with a heat pump**		
	Frick, G. 1978a. Verfahren zur Gewinnung von Wasser und Vorrichtung zur Durchfuhrung des Verfahrens. *CH Patentschrift* 606 644. Switzerland.	n.a.	No
	Frick, G. 1978b. Verfahren zur Gewinnung von Brauch-oder Trinkwasser und Vorrichtung zur Durchfuhrung des Verfahrens. *CH Patentschrift* 608 260. Switzerland.	n.a.	No
	Kajiyama Y. 1974. Appareil de climatisation fournissant de l'eau potable. *Demand de Brevet d'Invention.* Institut National de la Propriete Industrielle, Paris. No. de publication 2.219.119.	12	Yes
	Kuckens, A. 1983. Verfahren und Vorrichtung zum Gewinnen von Trinkwasser, insb. in Entwicklungsgebieten. *Patentanspruche* DE 31 42 136 A1. Bundesrepublik Deutschland.	n.a.	No
	Nasser, G. El Din and A. Pocrnja. 1980. Apparatus for the cooling and dehumidification of ambient air in regions having a hot and humid climate. *United States Patent* 4,182,132.	n.a.	No
	Swanson, R.J. 1972. Atmospheric water collector. *United States Patent* 3,675,442.	n.a.	No
	Zacherl, L. 1986. Vorrichtung zur Trinkwassergewinnung. *Patentanspruche* DE 3431 186 A1. Bundesrepublik Deutschland.	360	No
2a	**Water vapour concentrators using solid adsorbents**		
	Bennett, C.E. 1983. Heat energized vapor adsorbent pump. *United States Patent* 4,377,398.	n.a.	No
	Groth, W. and P. Hussmann. 1979. Process and system for recovering water from the atmosphere. *United States Patent* 4,146,372.	1×10^8	No
	Mitsubishi Electric Corp. 1981. Two column atmospheric water condensation apparatus, Japanese Patent 56-56216.	n.a.	No
	Takeyama, T., K. Azuma, A. Ikeda, T. Yamamoto, and S. Katsurada. 1982. Water producing apparatus. *United States Patent* 4,365,979.	n.a.	No
	Yamamoto, T., T. Takeyama, and A. Ikeda. 1981. Water producing apparatus. *European Patent* 39151.	n.a.	Yes
2b	**Water vapour concentrators using liquid adsorbents**		
	Lund, B.G.A. 1973. Extracting water from the atmosphere. *United States Patent* 3,777,456.	1.7×10^6	No
3	**Inducing and controlling convection in a structure**		
	Ockert, C.E. 1978. Device for extracting energy, fresh water and pollution from moist air. *United States Patent* 4,080,186.	n.a.	No

n.a. = not available.

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Adequate water supplies improve health and nutrition.

Daily water volume (litres/day) = Air-handling capacity of machine (m^3/s) × 86 400 s/day × Absolute humidity (g/m^3) × (1/1000) litres/g × efficiency of machine (%)

For example, a village of 250 people needs a subsistence water supply of 5000 litres each day. Say the absolute humidity at the village averages $10 g/m^3$ and the harvester operates at 50 per cent efficiency. The machine would have to process ambient air at the rate of $9.4 m^3$ per second.

This product water will lack the mineral content usually present in drinking water. Two patents address this issue with remineralization processes, as indicated in Table 1. A reservoir, sized for the needs of the users, will be required for storage. The water has to be treated like any other water source and must meet national water quality standards before being delivered to consumers.

The atmosphere contains $13 \times 10 m^3$ of water or 0.001 per cent of the planet's total water supply.[9] Even if all 5.3 billion people on earth used water from water vapour processors at the rate of 40 litres per day, they would consume only 0.00163 per cent of the available atmospheric water.

Although advanced technology is involved in some of the designs, this is not very different from using photovoltaics, which nowadays are considered to be appropriate technologies. Harmful environmental effects are likely to be minor. The water vapour that is condensed at any particular location will be insignifianct compared to the total water vapour content of the surrounding air.

Water-vapour processing can allow community control of the water resource. Air containing water vapour is everywhere. If suitable, locally owned and operated water vapour processors were developed, projected costs would be likely to decrease over time, as they do with any new technology. Further research is desirable because water vapour processing by its nature has only a minor environmental impact and allows the decentralization of drinking-water supply systems. ●

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